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TECHNICAL REPORT
GIT–ICS–81/11

LEVEL II ⑫

INITIAL EXPERIENCE WITH A LOCAL NETWORK ––—
NET/ONE   BY UNGERMANN–BASS, INC.

By

Philip H. Ensiow, Jr.
Paul D. Manno
Jeanette T. Myers

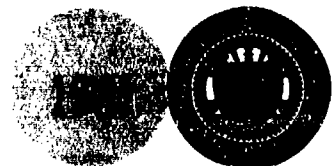⑫ ∂^6

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GEORGIA INSTITUTE OF TECHNOLOGY
**A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF INFORMATION AND COMPUTER SCIENCE
ATLANTA, GEORGIA 30332**

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THE RESEARCH PROGRAM IN
FULLY DISTRIBUTED PROCESSING SYSTEMS

INITIAL EXPERIENCE WITH A
LOCAL NETWORK ---
NET/ONE BY UNGERMANN-BASS, INC.

TECHNICAL REPORT

GIT-ICS-81/11

Philip H. Enslow, Jr.
Paul D. Manno
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October 1, 1981

The Georgia Tech Research Program in
Fully Distributed Processing Systems
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia   30332

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Georgia Institute of Technology   Net/One Local Network

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Net/One, the local area network produced by Ungermann-Bass, has been installed and operated in the Georgia Tech Fully Distributed Processing System's (FDPS) testbed. Currently Net/One interfaces with Prime 400, Prime 550, and PDP 11/45 computers which are located in the computer lab and several different types and brands of ASCII, asynchronous terminals. This report includes a description of the design and operation of the various Net/One components, a discussion of the rationale for the selection of Net/One for installation in the FDPS testbed, our initial experiences with ___

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Net/One including problems encountered and their solutions, and concludes with a description of the plans for future enhancements to its operation.

ABSTRACT

Net/One, the local area network produced by Ungermann-Bass, has been installed and operated in the Georgia Tech Fully Distributed Processing System's (FDPS) testbed. Currently Net/One interfaces with Prime 400, Prime 550, and PDP 11/45 computers which are located in the computer lab and several different types and brands of ASCII, asynchronous terminals. This report includes a description of the design and operation of the various Net/One components, a discussion of the rationale for the selection of Net/One for installation in the FDPS testbed, our initial experiences with Net/One including problems encountered and their solutions, and concludes with a description of the plans for future enhancements to its operation.

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CHAPTER 1

Background

1.1 Objectives for Installing a Local Network

The primary objective for installing a local area computer network was to provide a versatile research vehicle to investigate the concepts and utilization of local networking in a distributed processing environment. This research is part of the Georgia Tech Research Program in Fully Distributed Processing Systems (FDPS) which also includes research on distributed operating systems, distributed data bases, programming languages, theoretical and formal studies, security, fault tolerence, system utilization, physical interconnection and other topics.

A secondary objective was to provide relief to the 'growing pains' being experienced in the school's computer lab. Over a period of four years, the computer laboratory of the School of Information and Computer Science had grown from a very small computing facility consisting of two minicomputers and six terminals to its present size of ten minicomputers (some of which are quite large) accessible by more than 60 terminals. With each purchase of additional equipment, it had been necessary to provide a physical cable between each terminal and each computer that the terminal had to access. For terminals attached to multiple computers, a switch at the terminal selected the desired cable (and consequently the desired computer). Not only did this require a large number of individual cables but some of the cables had to be extremely long to accomodate terminals located over 500 feet from the computer lab. The cost of material and labor to provide and install these cables began to escalate and the resulting web of cables led to frequent failures which would sometimes take days to isolate and correct. This method of connecting terminals to computers also resulted in each terminal requiring multiple, dedicated, computer I/O ports, i.e. a dedicated port on each computer to which it had a cable. Since each terminal could be connected to only one computer at any given time and since many of the terminals were located in one-man offices and used infrequently, many of the computer ports remained idle most of the day.

A suitable local network promised solutions for each of these problems. The myriad of individual cables could be replaced by one coaxial

cable. With the local network, all computer ports were made available to all terminals; consequently, each computer needed to support only as many ports as the number of concurrent users expected or allowed. (Typically it has been observed that the number of simultaneously active users on each system is approximately 40% of the number of terminals that originally had a wired port to that system.) Multiple interconnecting cables, dedicated computer ports, and selector switches at the terminals would no longer be required.

1.2 Rationale for Net/One Selection

Net/One was selected as the local network research vehicle for three primary reasons. First, Net/One was one of the few local networks that was available for immediate shipment. Many of the other products considered were either still in the design phase or just beginning the prototype phase of development. Several of the local area network "products" were only proposals citing a "standard" mode of operation but not yet in the design phase. Second, Net/One provided the greatest configuration flexibility of the available products. The configuration and operation of Net/One is almost completely controlled through software and can be modified on a port by port basis. Third, Ungermann-Bass was interested in establishing a working relationship with Georgia Tech promising full product support as well as technical advice for the Georgia Tech developed enhancements to their product line.

CHAPTER 2

Net/One Description

2.1 Overview

Net/One is a general purpose, local area communications network that
supports point-to-point communications between digital devices such as com-
puter systems and terminals. Net/One consists of three logical components;
network interface units (NIU) which serve as interfaces between user
devices and Net/One, a Network Administrative Station (NAS) which supports
configuration and monitoring of the network, and a Network Development
System (NDS) which supports custom program development and testing. A
majority of the functions of NAS and NDS are implemented in a "special" NIU
and a ZILOG 1/20 microcomputer with 64K bytes RAM. (Some debugging aids of
the NDS are actually located on the regular NIUs).   These components are
connected by a standard coaxial cable supporting baseboard transmission
with a bandwith of 4 megabits/second. NIUs are connected to the coaxial
cable by an active device known as the tap which is composed of drivers
that transfer information between the cable and the NIU.

```
                                      Network      Network
                                    Administrator  Development
          Digital Devices             Station       System
            \    |    /                  |            |
          _____       _____|_____|_____
          |              |       |     |              |      |
          | Network |            |  | Network |    _____   |
          |Interface|            |  |Interface|<-->|ZILOG|   |
          | Unit    |            |  | Unit    |    |_____|   |
          |_____|             |  |_____|             |
              |                  |_____|_____ __|
             _|_                      _|_
       |----|Tap|------------------|Tap|----|
                  coaxial cable
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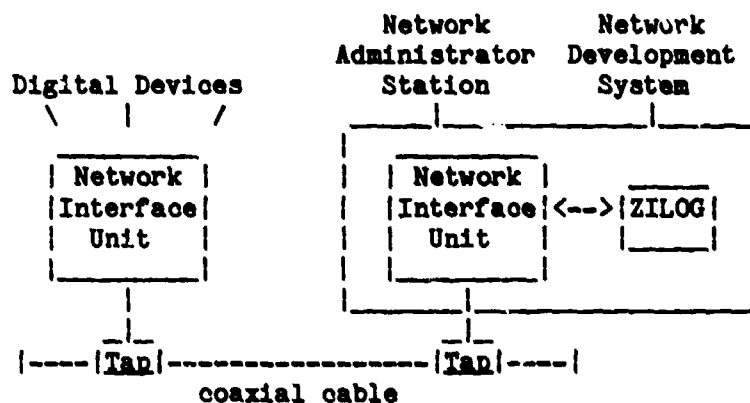
Figure 1. Diagram of a Net/One Local Network

2.2 Network Interface Units (NIU)

One NIU can support up to 16 asynchronous devices, or eight 8-bit or 4
16-bit parallel devices that may differ in type, transmission rate, parity,
flow control, disconnect sequence, etc. As shown in Figure 2, the major
components of an NIU are the transceiver interface, the network processor

board and the application processor boards. They communicate via an
8Mbyte/second internal data bus. The transceiver interface performs
address recognition, packet transmission to and from the coaxial cable,
packet framing and error detection. Each processor board can support 4
serial and either two 8-bit or one 16-bit parallel devices. A Z-80
microcomputer, 64K bytes RAM and 4K bytes of PROM located on each board are
used to provide a software interface to each device. In addition to device
interfacing, the network processor board performs many functions for all
NIU components such as controlling traffic inside the NIU, establishing and
disconnecting virtual circuits, and building packet headers for outgoing
packets.

```
 _____
|  ____    _____          __       |
| |    |  |  _____  |_            |  |      |
| 0 - 3 |_||                    |_             | |       |
| applica-| |   Z-80 micro.        | <------------> |  |       |
| tion    |_|  64K bytes RAM     |                | |       |
| processor |  4K bytes PROM      |                | |       |
| boards  |_____|                | |       |
|          || || || ||   || ||                  | |       |
|          4 serial  2 8-bit                     | |       |
|            ports   parallel ports     |Internal|       |
|                                       |Data Bus|       |
|          _____         |(8Mbytes|       |
| Network  |  Z-80 micro.        |       | | /sec)|       |
| Processor|  64K bytes RAM     | <------------> | |       |
| Board    |  4K bytes PROM      |                | |       |
|          |_____|                | |       |
|          || || || ||   || ||                  | |       |
|          4 serial  2 8-bit                     | |       |
|            ports   parallel ports              | |       |
|          _____                  | |       |
|         | transceiver    <------------> |       |
|         |_____|             |_|       |
|_____|_____|
                        _|_
 ------------------- |Tap|----------------------------
                 coxial cable (4Mbits/sec)
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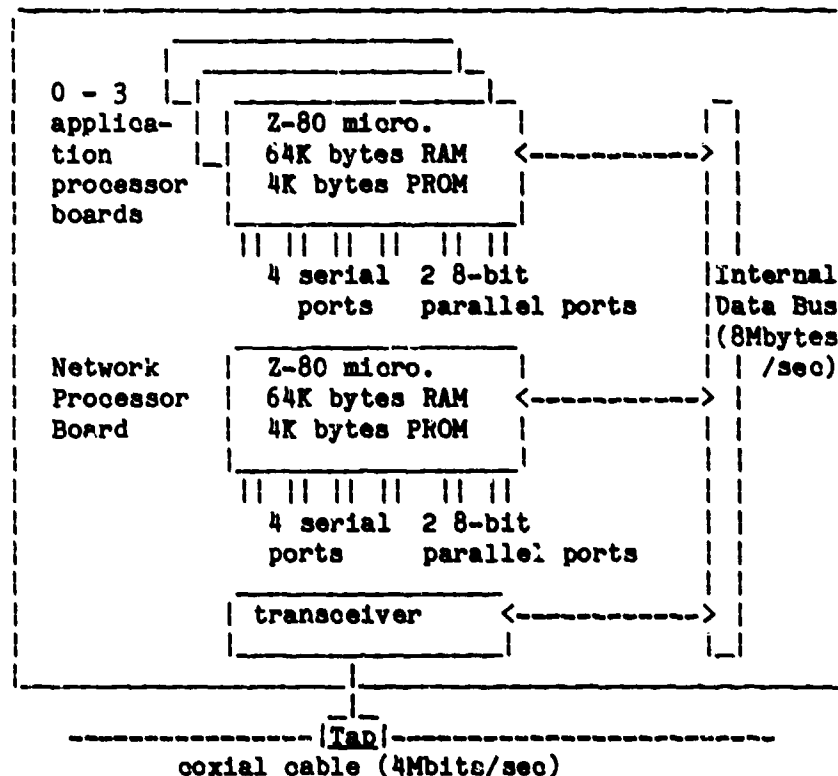
Figure 2. Diagram of a Network Interface Unit (NIU)

2.3 Network Administrator Station (NAS)

     Network management is the responsibilty of the NAS. This includes
configuring the network, monitoring network traffic, logging network events

and servicing requests from NIUs for down loading. As mentioned earlier,
the functions of the NAS are implemented on a special NIU and a ZILOG 1/20
microcomputer.

Each device connected to an NIU board is controlled by a separate
process which must know that device's characteristics in order to correctly
interface with it.   Figure 3 contains an example of the configuration
parameter list that associates device characteristics with individual NIU
ports; included in Figure 3 are the characteristics of two devices on our
network, an ordinary CRT and a PRIME computer port.

When an NIU is initially powered up it automatically requests down-
loading from the NAS.   While the network is in operation, an NIU can be
downloaded by pressing the "reset" switches located on the front panel of
the NIU.   When the NAS receives the request, it asks the ZILOG microcom-
puter to retrieve kernel code, programs and device characteristics to load
in the NIU.

The NAS has a few other features. The NAS console is used as a log-
ging device where NIU downloading actions and errors in the network are
recorded.   The Net/One systems administrator can connect to the NAS and use
special adminstrator commands to examine devices, create virtual circuits
between two remote devices, etc.
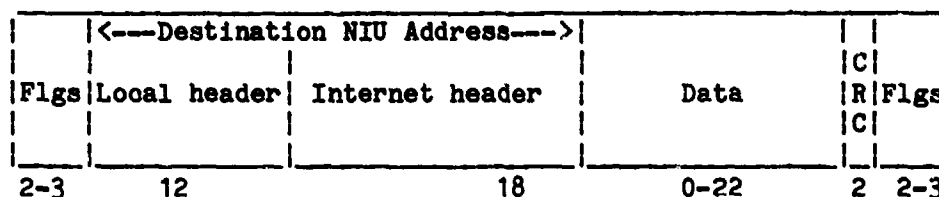
2.4 Network Development System (NDS)

The NDS can be used by the Net/One user to write his own programs for
controlling the activities of the network. Development tools include those
supported by the ZILOG 1/20 microcomputer system, i.e. editor, debugger,
assembler, file utilities etc. plus a library of programs supplied by
Ungermann-Bass to support customer programming. There is an interactive
NIU debugger program and each NIU has a test toggle switch that causes down
loading with user specified test programs and data instead of the data
normally down loaded by the NAS.   In addition, each processor board
(network and application) is furnished with a memory debugger and a special
set of sockets for debugger PROMs.

Configuration Program	CRT	PRIME Computer
Is this device serial async, serial sync or parallel	serial async	serial async
Does it use standard or extended RS-232 signalling	std	std
How many NULs after each linefeed	0	0
How many NULs after each carriage return	0	0
When echoing enabled, add linefeed after each carraige return	No	No
How many stop bits	2	2
How many data bits per character	7	7
Odd parity, Even parity, or No parity	Odd	Odd
Does this device support flow control	No	Yes
Does it use characters or RS-232 line signals	NO	line signals
CTS:RTS or DSR:DTR	na	DSR:DTR
Is this a command device	Yes	No
Is it also a data device	Yes	na
Command mode initiation character	NUL	na
Backspace character	BS	na
Line delete character	DEL	na
Completion character	HT	na
Should NIU commands be echoed	Yes	na
Should NIU command responses be suppressed	No	na
Does this device support lower case	Yes	na
Disconnect sequence	/LF/D/	/DEL/EM/EM/EM/
Should circuit data be echoed locally	No	No
Input buffer size (2-254)	90	10
Output buffer size (2-254)	60	25
Input buffer flow control threshold	55	6
Baud rate	9600	9600
Should a circuit be initiated from this device at startup	No	No

Figure 3. The Configuration Program

2.5 Net/One Operation

Net/One supports the CSMA/CD (Carrier sense multiple access/collision detection) access protocol. Both virtual circuits and datagrams are allowed. Packets are broadcast over the coaxial cable and "picked up" by those NIU's to which they are addressed. Figure 4 gives the format for a Net/One packet. The local destination header contains the destination of the packet within the local network. If the packet is being sent to another local network then the local destination is the "gateway" NIU to that other network. The internet destination header then defines the final destination NIU of the packet in the other network.

```
      |<---Destination NIU Address--->|                   |  |    |
      |            |                  |                 |C|    |
 |Flgs|Local header| Internet header  |      Data       |R|Flgs|
 |            |                  |                 |C|    |
 |____|_____|_____|_____|__|____|
 2-3      12                 18               0-22      2   2-3
```

(numbers below packet represent field length in bytes)

Figure 4. A Net/One Packet

2.5.1 Device to Device Communication

Each NIU has a network address, i.e. 27. The network processor board is always known as the "a" board and its ports have addresses such as 27a1, 27a2 ... 27a6. Application boards are known as "b", "c" and "d" boards and their ports follow the same addressing scheme, i.e. 27b1, 27c4, 27d6 etc.

A device can communicate with another device by requesting a virtual circuit to an address; this is done utilizing the connect command, i.e.,

        connect 27c2

If the device connected to 27c2 is free (a device may participate in only one virtual circuit at a time) a virtual circuit is established. Any data transmitted by a device at one end of a virtual circuit is delivered to the other end in the same order as transmitted. Either device may disconnect/disestablish the virtual circuit at any time.

All devices have a device "type" which can be either command, data or
both command and data. Command devices can request virtual circuit connec-
tions, data devices cannot request but may accept virtual circuit connec-
tion requests and a command/data device may do either.

2.5.2 Sending and Recieving Packets

NIUs control packet traffic in the network. When a device or com-
ponent of an NIU supplies the data for a packet the network processor board
builds a packet header for that data and sends the packet to the transmit-
ter.   The transmitter frames the packet, adds a CRC, and places it in a
FIFO queue for transmission. When the packet arrives at the head of the
queue, the receiver notifies the transmitter to place the packet on the
coaxial cable at a time when it detects no other traffic on the cable.   If
the recet' detects data on the network while the packet is being trans-
ferred, i. signals a "collision" to the transmitter.   The transmitter
broadcasts a collision message to all other NIUs; those NIUs that were
transmitting will attempt a retransmission after a random time delay.   The
local transmitter will also retransmit the packet after a random time
delay. Transmitted packets are kept in a circular queue where they can be
retrieved for retransmission if necessary.

When a packet addressed to a receiver's NIU is detected on the or x,
it is queued in a FIFO buffer. A CRC check is made; if an invalid packet
is found, it is removed from the queue and a message is broadcasted
requesting retransmission of the packet. (All packets have a unique packet
id). If the packet is valid an interrupt is generated to the processor
board which will look at the packet header and, depending on the device to
which the packet is addressed, will either receive the data or notify one
of the applications boards to receive the data.

2.6 Other Enhancements Available for Net/One

Up to this point we have described the local network that we have
installed in the Information and Computer Science Lab at Georgia Tech.
Since that installation, Ungermann-Bass has produced a 10Mbit/second local
network (to which we could upgrade) and optional Ethernet compatible
software for the 10Mbit/second network.

Our ZILOG microcomputer system currently uses floppy disks. A Winchester disk drive is now available which, along with an IEEE 448 bus structure between the microcomputer and the special NIU, reduces the downloading time of an NIU processor board from approximately 90 seconds to 19 seconds.

CHAPTER 3

Our Experiences With Net/One

3.1 Hardware Installation and Testing

Net/One was installed in the ICS computer lab in September, 1980. The original configuration included 9 Network Interface Units (NIU's), 1 Network Administration System (NDS) and 1 Network Development System. This equipment allowed for 108 general purpose asynchronous ports. (We do not use the parallel ports.)

3.1.1 Flow Control

Net/One supports three methods of flow control: using ASCII control characters, using RS-232 Request-To-Send and Clear-To-Send (RTS/CTS) control lines, or using the Data-Set-Ready and Data-Terminal-Ready (DSR/DTR) hardware control lines. None of these methods were completely suitable for our operation. Character flow control was not a viable option because several applications on the PRIME computer system already used all of the ASCII control characters; e.g. the full-screen editor. (Any of the standard ASCII control codes except null can be used; typically DC3 (ctrl-S) is used to stop output and DC1 (control Q) is used to restart output.) The asynchronous communications hardware on the PRIME computers did not support RTS/CTS hardware lines nor did they support a DSR control line.

A solution was eventually found involving the use of the PRIME's carrier detect line (normally used for modem control) as a DSR control line. The Primos operating system was modified to use the carrier detect line as a flow control sense and the PRIME's carrier detect and DTR lines were wired to the networks DTR and DSR respectively. While implementing this solution, an error in the Primos operating system causing incorrect manipulation of the DTR control line was a. covered and fixed.)

We encountered yet another flow control problem caused by devices at one end of a virtual circuit receiving data at much slower speeds than being transferred by host computers at the other end. Net/One would not send an x-off signal to a transmitting device until the receiving buffer was 8 characters away from being full. If an x-off signal was sent to a PRIME computer, it was very likely that more than 8 characters would be

sent to the device before the PRIME would suspend transmission. As a result, slower devices like hardcopy terminals were losir · characters. Ungermann-Bass solved this problem for us by making the input buffer flow control threshold user-programmable in the next software release. This feature also enabled us to connect the PDP-11/45 to Net/ONE. Our 11/45 did not support flow control; however by setting the transmission speed to 4800 baud and setting the input buffer threshold to a high value we were able to get reliable transmission.

3.1.2 Parity

We were required to change our terminal parity standard from mark parity (always on) because the Net/One software restricted transmitted ASCII data characters to have the parity bit odd, even, or always off (space parity). No provision was made to use mark parity or to simply ignore the parity bit on input. Since some of the terminals we were currently using could not generate either even or space parity, odd parity was chosen as the standard for our terminals. (Since computer ports were data devices, we kept them configured for mark parity. If Net/One encounters a parity bit set to an unexpected value, it simply "ignores" the byte (i.e. Net/One passes it through to the device at the other end of the circuit without examining the contents for a recognizable command.)

3.1.3 Coaxial Cable Connections and Terminators

After solving flow control and parity problems the network was still unstable. It took us a while to discover that the cause was a faulty terminator that was reflecting signals back into the coaxial cable. We also discovered that connecting the pieces of the coaxial cable is not easy or foolproof. If one connection anywhere along the coaxial cable is faulty, the entire local network becomes unstable. Best results were obtained when we connected the cable in a straight line (i.e. no "T" connections).

3.2 Software installation and testing

3.2.1 Release 1.2

The original Net/One software, release 1.2, provided the following commands to Net/One users:

Command	Explanation
connect device <address>	virtual circuit request
<LF>D	virtual circuit disconnect
list disconnect	list disconnect command
list address	list my network address

Figure 5. Some Net/One User Commands

Commands could be abbreviated to the first letter of each word, i.e. "c d 27a3" for "connect device 27a3".

There were a few shortcomings in release 1.2. Users had to know all of the specific network addresses assigned to a computer system that they wanted to access. Network address assignment was governed more by physical proximity of the NIU which did not necessarily follow a logical order. If for some reason, a computer port address had to be moved, all users needed to be notified of the change. If the first connect was unsuccessful because the port at the specified address was already participating in another virtual circuit, the user was required to repeat the connect sequence for other addresses until a free port was found.

Other problems resulted from Net/One's non-transparent transmission of some characters. Specifically, some of the ASCII control characters were incorrectly interpreted and/or were not passed through the virtual circuit. This problem was first observed with programs that controlled the cursor positioning on some brands of CRT terminals. It was later discovered that the break key, used by the Prime computers as a software interrupt signal, was transmitted through the virtual circuit as an ASCII NULL which the PRIME computer ignored.

3.2.2 Release 2.1

In March, 1981, release 2.1 arrived. There were a few new features and several improvements over the original software release. The most wel-

come of the new features was the global network name server. This feature
allowed a local network user to request a virtual circuit by specifying a
symbolic name. The name server then broadcasted the request to all network
ports. Any of the network ports that had been configured to respond to
that name and that were not currently part of a virtual circuit would ack-
nowledge the request. When the circuit was established, the user received
confirmation showing the physical network address that accepted the connec-
tion request. If all network ports configured with that symbolic name were
currently tied up in another virtual circuit, the user received the message
'All ports are busy'. If no network ports were configured with that name
or if none of the configured ports were operational, the user received the
message 'No resource answers by that name'.

Other major enhancements were made to the configuration program. The
program was much easier to use and added such features as extended RS-232
line signals for serial and parallel ports and user programmable input
buffer flow control thresholds.

3.3 In-House Modifications to Net/One Software

With a small modification to the PRIMOS operating system and correc-
tions to the Net/One software from Ungermann-Bass, we implemented a method
of forcing a virtual circuit disconnection when a Prime computer user log-
ged off. The local network made logging on and off a two step process:
requesting/disconnecting a virtual circuit and logging-on/logging-off a
computer system. Many users were logging off but not disconnecting the
virtual circuit thus not freeing that computer port for another user. This
modification caused automatic virtual circuit disconnection when the user
logged off. In order to implement this facility, it was necessary to
reconfigure all our network computer ports and computers to use odd parity.
(Since we wanted Net/One to recognize the disconnect sequence issued by the
computer, each character of the disconnect sequence had to have the parity
bit set to something that Net/One understood.)

Another correction to the Net/One software removed the sensitivity to
ASCII control codes. This correction allowed the use of cursor-positioning
programs with no restrictions.

3.4 Current performance

Curre tly, we have 10 NIUs with 124 available ports of which only 11 are not yet connected to any device. 44 computer ports provide access to five PRIME computers running Primos and a PDP 11/45 computer running Unix version 7. Most devices run at 9600 baud.

We have not as yet made any in-depth performance analyses of Net/One. However, we have had Net/One for almost a year and once installed we never witnessed any component failures nor were we ever required to bring the network down because of hardware or software problems (and we purchased one of the first Net/One networks manufactured). Our computer systems perform character echoing for all terminals, and even with heavy terminal activity we have never noticed any delays induced by Net/One. Finally, both our novice and very experienced users have found that Net/One is easy to use.

3.5 Unsolved Problems

There remain a few problems with Net/One that both Georgia Tech and Ungermann-Bass are attempting to solve. Some of these problems are addressed in Revision 3.0, soon to arrive. Net/One still transmits break characters as ASCII NULLS. Users cannot send one character that matches the first character of the disconnect sequence because that character is not transmitted until another character not in the disconnect sequence is typed. Also, the local network remains sensitive to the ASCII parity bit.

Occasionally, a virtual circuit is broken by the network. This leaves the computer user logged in to the computer. Since the circuit to that computer no longer exists, any other terminal user may connect to that computer port and find himself in the middle of the terminal session of the user whose circuit was broken. (We have just recently received a patch for Revision 2.1 software that appears to take care of this problem). Also, occasionally, a number of Net/One ports becomes unavailable to the rest of the local network for no reason. Typically, this problem occurs with groups of 4 network ports up to and including an entire NIU (16 ports). In order to make these ports usable again, it is necessary to reload the NIU.

Reloading an NIU is very easy. It requires pressing reset switches on the front panel of the NIU and then waiting approximately 90 seconds per board. However, there is no provision for reloading only one board. If we need to reconfigure a port or if a board hangs, we must ask all users con-

nected to other ports on the NIU to log off until the NIU is reloaded.

CHAPTER 4

Future Plans for Net/One

4.1 Security

Working closely with Ungermann-Bass, we plan to develop a security system within the local network. First, we expect to implement a password security system requiring a password to be supplied and checked before a new virtual circuit can be established. This will be used to control access to those systems that require additional security such as those used for research. Our general access computers will not require a password for connection.

We also plan to implement an access list security system within the local network. The access list security will allow connections to specific computers from a list of terminal locations. This will serve to further deter non-authorized usage of sensitive resources.

Related to the security system will be the implementation of a one-step login process. This would involve a command such as

    login <username> <project>

that would cause the local network to create a virtual circuit to the computer system associated with the username and project information and then execute a surrogate login for the user. The next thing that the user would see is the password prompt.

4.2 X.25

We propose to use a portion of the X.25 interface between the host and the NIU to act as an X.25 DCE to support multiple virtual circuits on one physical connection. Also, an implementation of the X.25 DTE protocol in an NIU is desired to allow direct connection between Net/One and an X.25 Public Packet Switched Network, e.g. Telenet.

4.3 Performance Studies

We plan to carry out some performance studies on the local network. Particularly, we would like to find out how much traffic it takes to induce a noticeable degredation of Net/One performance.

4.4 Additional Service

We are planning to expand the current local network hardware to support more terminal users and computer systems. Figure 6 contains the diagram of our future local network. The first step of the expansion has been to order 20 additional Net/One ports raising our current network port count to 144. (When fully expanded, the Net/One local network can support 255 NIU's for a total of 4080 general purpose asynchronous ports). We will eventually support the following computers:

[1] IBM Series/1 running under the EDX operating system. We currently have three of these machines in our computer lab used for both academic and research purposes.

[2] HP 1000 F series under the RTE IV B operating system. This system will be used as a graphics support processor driving several Hewlet Packard graphics devices including a plotter and color graphics terminals. This system supports mainly an academic user community.

[3] VAX 11/780 running under the VAX Unix version 7 operating system. This system will also be used to link Georgia Tech to CSNET, the national computer science network.

[4] CDC Cyber 74 running under the NOS version 1.4 operating system. This computer along with a CDC 6400 supplies the Georgia Tech campus with general computing resources.

[5] Several single user microcomputer workstations capable of stand-alone network operation.
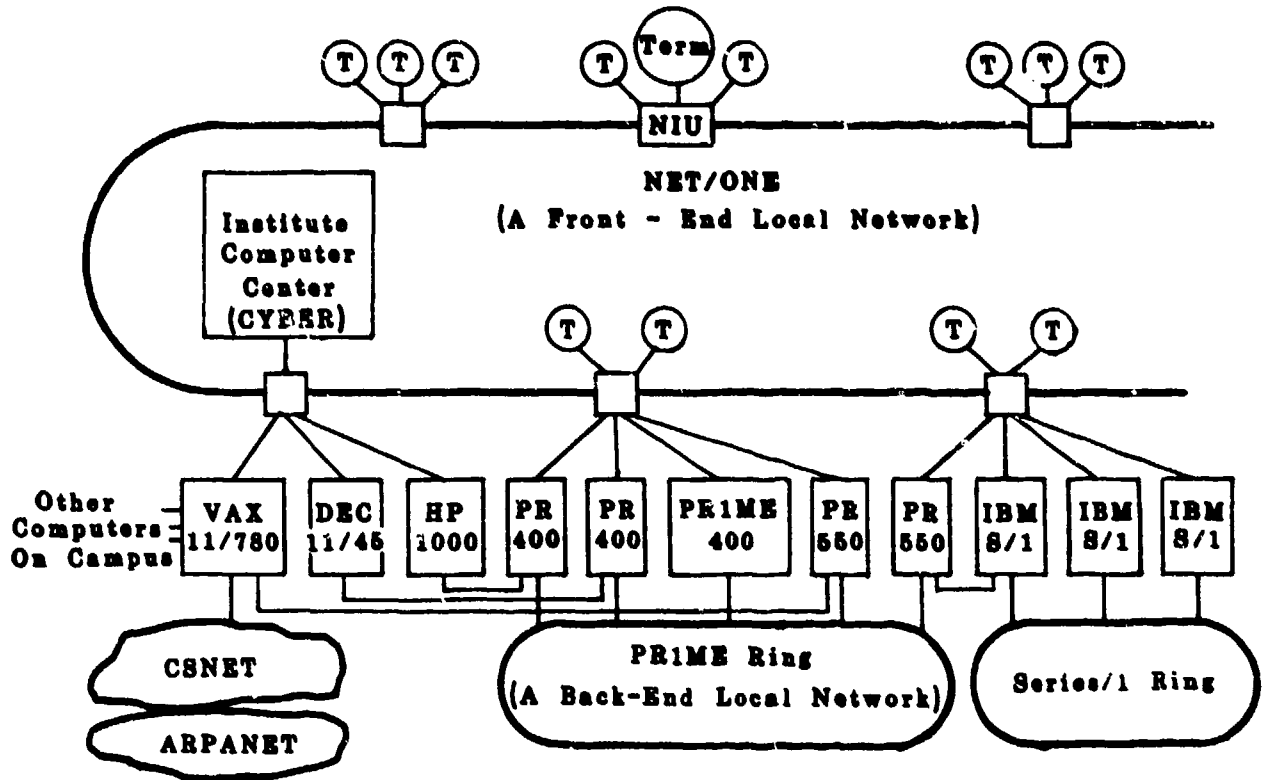
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Figure 6. Our Future Local Computer Network